PRIMARY CONSUMER AND DETRITIVORE COMMUNITIES (DIPTERA: EPHYDRIDAE) IN NEWLY RESTORED AND CONSTRUCTED WETLANDS

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Abstract.—Although maximum diversity of higher Diptera has been reported in the interface between wetlands and other ecosystems, few studies have documented successful restoration of wetland insects within these ecotones. The consistent collection of shore flies (Diptera: Ephydridae) supports the hypothesis that shore flies rapidly colonize newly restored and constructed wetlands at Miami Trace and Winton Woods county Parks, Hamilton County, Ohio. Rapid colonization of shore flies exhibited a temporal shift that is associated with aquatic vegetation colonization, growth, and maturation. Species composition of shore-fly communities suggests that a minimum of five general nutrient sources were exploited in newly established wetlands, and shore flies may be an essential part of the establishment of complex food webs. A comparison of Sorenson and diversity indices suggests that shore-fly communities in constructed and restored Ohio wetlands were distinct species assemblages. Significant differences among shore-fly communities are attributed to variation in species abundance. Although restored and constructed wetlands were flooded during 1998, variation in species abundance and monthly species accumulation suggests that the development of ecosystems within each wetland was asynchronous.

Key Words: restored wetlands, Diptera, Ephydridae, colonization, community diversity, food webs

In many regions of the United States, the restoration of wetlands has been initiated to provide habitat for vertebrate species. The success of bird, amphibian, and mammal recolonization in wetlands is directly related to the type, quality, and abundance of food resources within wetland ecosystems (Wilson 1987). One of the major sources of food for waterfowl, shore birds, and fish species is insects (Martin and Uhler 1939, Zahl 1967, Clarke 1976, Murkin and Batt 1987). During egg laying and brood rearing, adult and juvenile ducks consume invertebrate food (including insects) (Krapu and Swanson 1975, Bataille and Baldassarre 1993) to obtain the protein that is nec- essary for reproduction and rapid growth (Driver et al. 1974). Decreased availability of food has been associated with duckling mortality (Johnson et al. 1992, King and Brazner 1999), and duckling brood avoidance and abandonment of wetlands that have small numbers of invertebrates (Cooper and Anderson 1996). Although the importance of insect resources to waterfowl development has been recognized, an understanding of the contributions of insects to wetland food webs is limited (Rosenberg and Danks 1987, Batzer and Wissinger 1996, Hansen and Castelle 2000). As Batzer and Wissinger (1996) stated, many of the previous experiments and assumptions con-

cerning wetland insect ecology require re-evaluation to improve the management of insect resources as waterfowl food. Foundations for regulating insect and waterfowl communities are in the initial stages of development (Batzer and Wissinger 1996).

Previously, a majority of wetland investigations have focused on plant communities, soils, hydrology, chemical processes, benthic invertebrates, and vertebrate populations, such as waterfowl (Sharitz and Batzer 1999). Although maximum diversity of higher Diptera is at the interface between mature wetlands and other ecosystems (Deonier 1965, LaSalle and Rozas 1991, Marshall 1994, Scheiring and Foote 1973, Steinly 1986, Thier and Foote 1980, Keiper et al. 2002), and the greatest production of insect biomass is found in sparse emergent vegetation zones (Voigts 1976, Orains 1980, Kaminiski and Prince 1981, McLauglin and Harris 1990), only a few investigations have focused on the successful restoration of wetland macroinvertebrates that are found in the water column and/or sediments (Danell and Sjoberg 1982, Florida Department of Environmental Protection 1994, Brown et al. 1997). The attraction of shore flies to artificial pools and other habitats in a constructed wastewater treatment wetland at 2 days post-flooding and the establishment of shore-fly populations suggest that colonization by these species was not incidental (Keiper and Walton 2002, Keiper et al. 2002). Although two investigations have focused on Diptera that inhabit soil and consume decaying vegetation in restored Florida (Streever et al. 1996) and Washington (Hansen and Castelle 2000) wetlands, studies of primary consumer richness or abundance have not been reported.

Layton and Voshell (1991) suggested that an increase in habitat diversity would most likely lead to increases in invertebrate diversity within wetland ecosystems. It is common for detritus-feeding insects (i.e., insects that feed on decaying plant and animal tissues) to dominate areas that contain newly flooded decaying organic materials (Layton and Voshell 1991). However, as an area matures, plant detritus decreases and production of unicellular and multi-cellular algae and macrophytes increases (Layton and Voshell 1991) resulting in increased primary consumer abundance and species richness. Although Batzer and Wissinger (1996) did not monitor primary consumer communities, their review suggests that detritivore communities are not affected by macrophyte and algal growth. They suggest that detritivore populations either remain constant or increase where multi-cellular plants were cut and debris removed.

In this paper, evidence is presented to document the initial colonization of newly restored and constructed wetlands by shore-fly species that have been associated with the consumption of detritus and primary production. Temporal shifts in the richness and abundance of primary consumers and detritivores i.e., shore flies are associated with the growth of macrophytes and maturation of newly established wetlands. Shore-fly diversity, relative abundance, richness, and similarity values from these wetlands are compared. Diversity values are compared with a t-test to identify significant differences in shore-fly communities.

MATERIALS AND METHODS

During 1997, the Hamilton County Park District completed the restoration of a single wetland at Miami Trace, and the construction of two wetlands at Winton Woods, Hamilton County, Ohio. At Miami Trace, the renewed flooding represents a restoration of a wetland that was surveyed and described before the settlement of Ohio. A single wetland was leveed at Miami Trace County Park without basin alteration, and is located northwest of New Haven and approximately, 0.55 km east (39°17.3'N, 84°44.8'W) of a larger restored wetland complex. Before wetland restoration, the area was covered with old-field vegetation and was well drained. Post-restoration vegetation consisted of scattered stands of Ty-

pha latifolia L. and patches of filamentous algae that were surrounded by unvegetated mud shores. The Winton Woods County Park (Winton Woods, Ohio) sites consist of two basins on the northern edge of the park that are named Mallard (39°15.9′N, 84°31.1′W) and Heron (39°15.9′N, 84°30.9′W) Wetlands. These wetlands were constructed to control precipitation run-off from the surrounding watershed and to provide habitat for vertebrate species. Mallard Wetland was bordered on the south by a steep grass shore while the wetland interior contained scattered stands of *T. latifolia* mixed with *Sparganium americanum* Nuttall, *Alisma subcordatum* Raf., and *Carex*. Heron Wetland had a similar grass shore on the south side that was well drained. The shallow slope of the northern shore of Heron Wetland promoted the retention of soil water that sustained the dense growth of sedges and scattered *Sagittaria latifolia* Willd. on the shoreline. Emergent *Ranunculus flabellaris* Raf. occupied two thirds of the wetland pool. Although trace amounts of precipitation fell during July–September, the Winton Woods sites held water at a fairly constant level until mid August. During late August through September, areas of limestone sediment in both Winton Woods wetlands were exposed that was covered with sparse plant debris. As the season progressed, larger areas of sediment were exposed in Mallard Wetland and these mud shores were colonized by widely scattered clumps of *Setaria glauca* Kuntze (yellow foxtail), grass (-es), and *Sp. americanum*, while *Carex* sp. and *Sa. latifolia* grew on newly exposed mud shore at Heron Wetland. Visual evidence of leaf mining confirmed that pioneering grasses were colonized by dipteran primary consumers.

Bi-weekly collections of shore flies were initiated at Miami Trace and Winton Woods in May and continued through October 1998. Wetlands were subdivided into habitats that were characterized by substrate and vegetation types and sampled with a modified aerial sweep net (150 net sweeps per habitat) (Scheiring and Foote 1973; Regensburg 1976; Steinly 1978, 1986, 1990, 2001). One sweep sample is the combination of a back and forth movement of the net through a habitat. Sweep net sampling is a quick and inexpensive means of sampling diverse communities of invertebrates (Murkin et al. 1983, Cheal et al. 1993). The size of sampling areas and the number of net sweeps were equal among habitats. Plant debris was removed immediately from the samples and stored temporarily in petri dishes. Mounted and unpinned specimens were identified, labeled and counted. Mounted and vialed voucher specimens are deposited in the Miami University Insect Collection.

The percentage relative abundance is calculated with the formula R. A. = $A_1/N \times 100$, where R. A. is the percentage relative abundance, A_1 is equal to the abundance of each species, and N is the total number of shore flies within the wetland. The percentage ranges are characterized as follows: 1–2% rare (r), >2–8% occasional (occ), >8–14% common (c), >14–25% abundant (a), and >25–100% very abundant (va) (Deonier 1965; Scheiring and Foote 1973; Deonier and Regensburg 1978; Steinly and Deonier 1980; Steinly 1984, 1986, 1990).

The Shannon-Wiener diversity index (H′) was calculated for all wetlands because it incorporates both species richness and abundance (Scheiring 1974). Shore-fly diversity (H′) values for each wetland were compared with a *t*-test to identify differences in shore-fly communities (Zar 1984). Diversity is calculated by: $H' = -\Sigma\, p_i \log_{10} p_i$ where p_i is n_i/N, n_i is the number of individuals of the ith species of the habitat being considered, and N is the total number of individuals per habitat. H′ is essentially dimensionless and usually not affected by sample size (N) (Olive and Dambach 1973, Scheiring 1974). Newly restored wetland habitats of comparable area were sampled for approximately the same amount of time and probable differences in richness and abundance of shore-fly species reflect bio-

Table 1. Shore-fly species abundance and relative abundance in newly constructed and restored Ohio wetlands.

	Mallard Wetland Winton Woods			Heron Wetland Winton Woods			Restored Wetland Miami Trace		
	Number	R. A. (%)		Number	R. A. (%)		Number	R. A. (%)	
Allotrichoma simplex (Loew)*	81	(2.45)	occ	44	(4.64)	occ	277	(49.29)	va
Dichaeta caudata (Fallén)*	2	(0.06)	r	3	(0.32)	r	—	—	—
Discocerina brunneonitens Cresson*	43	(1.30)	r	1	(0.11)	r	—	—	occ
Discocerina obscurella (Fallén)*	2153	(65.10)	va	196	(20.65)	a	32	(5.71)	occ
Ditrichophora exigua Cresson*	1	(0.03)	r	—	—	—	2	(0.36)	r
Hyadina albovenosa Coquillett	—	—	—	35	(3.69)	occ	—	—	—
Hyadina binotata (Cresson)	1	(0.03)	r	12	(1.26)	r	3	(0.54)	r
Hyadina pruinosa (Cresson)	1	(0.03)	r	1	(0.11)	r	—	—	—
Hydrellia formosa Loew	—	—	—	7	(0.74)	r	—	—	—
Hydrellia griseola (Fallén)	279	(8.44)	occ	102	(10.75)	c	62	(11.07)	c
Hydrellia ischiaca Loew	1	(0.03)	r	—	—	—	—	—	—
Hydrellia tibialis Cresson	116	(3.51)	occ	47	(4.90)	occ	53	(9.46)	c
Hydrochasma leucoproctum (Loew)*	24	(0.73)	r	—	—	—	3	(0.54)	r
Leptopsilopa atrimana (Loew)*	1	(0.03)	r	—	—	—	—	—	—
Lytogaster excavata (Sturtevant and Wheeler)	1	(0.03)	r	8	(0.84)	r	—	—	—
Nostima scutellaris Cresson	3	(0.09)	r	8	(0.84)	r	—	—	—
Notiphila adusta Mathis*	2	(0.06)	r	9	(0.95)	r	3	(0.54)	r
Notiphila loewi Cresson*	2	(0.06)	r	6	(0.63)	r	—	—	—
Notiphila pauroura Mathis*	34	(1.03)	r	22	(2.32)	r	—	—	—
Notiphila phaeopsis Mathis*	41	(1.24)	r	20	(2.11)	r	—	—	—
Ochthera anatolikos Clausen	2	(0.06)	r	—	—	—	4	(0.71)	r
Paralimna punctipennis (Wiedemann)	79	(2.39)	r	79	(8.32)	occ	11	(1.96)	r
Parydra aquila (Fallén)	10	(0.30)	r	5	(0.53)	r	—	—	—
Parydra breviceps Loew	57	(1.72)	r	13	(1.37)	r	—	—	—
Parydra quadrituberculata Loew	43	(1.30)	r	3	(0.32)	r	4	(0.71)	r
Pelina truncatula Loew	—	—	—	—	—	—	1	(0.18)	r
Philygria debilis (Loew)	—	—	—	1	(0.11)	r	35	(6.25)	occ
Polytrichophora orbitalis (Loew)*	168	(5.08)	occ	36	(3.79)	occ	15	(2.68)	r
Psilopa dupla Cresson	8	(0.24)	r	—	—	—	3	(0.54)	r
Ptilomyia enigma Coquillett	27	(0.82)	r	3	(0.32)	r	—	—	—
Scatella favillacea Loew	—	—	—	—	—	—	25	(4.46)	occ
Scatella obsoleta Loew	7	(0.21)	r	—	—	—	12	(2.14)	r
Scatella paludum (Meigen)	5	(0.15)	r	—	—	—	2	(0.36)	r
Scatella stagnalis (Fallén)	77	(2.33)	r	147	(15.49)	a	8	(1.43)	r
Setacera atrovirens (Loew)	—	—	—	—	—	—	1	(0.18)	r
Typsilopa atra Loew*	16	(0.48)	r	125	(13.17)	c	6	(1.07)	r
Zeros flavipes (Williston)	22	(0.67)	r	16	(1.69)	r	—	—	—
Total =	3307			949			562	=4818	

* Known Detritivore Species.

logical differences among wetlands (Scheiring 1974).

The community composition of each wetland was compared by means of the Sorenson Index of Similarity (I). Similarity is calculated with the formula $I = 2\,C/(A + B)$, where I is the index of similarity, C is the number of species shared, A is the number of species in habitat A, and B is number of species in habitat B (Scheiring and Deonier 1979, Steinly 1984). The Sorenson index ranges from 0 when there is no similarity (no species shared) between habitats to 1 when there is complete similarity.

RESULTS

During May through October of 1998, 4,818 shore flies were collected from the newly restored and/or constructed wetlands within Miami Trace and Winton Woods County Parks, respectively (Table 1). Collections from Mallard and Heron wetlands at Winton Woods, and the restored wetlands at Miami Trace contained 31, 26, and 21 (Table 1) species of shore fly within samples of 3,307, 949, and 562 specimens, respectively (Tables 1–4). Of the total number of shore flies, detritivores accounted for approximately 78, 49, and 60% of the ephydrid communities within Mallard, Heron, and Miami Trace wetlands, respectively (Table 1). Approximately 86.7%, i.e., 4,177 of the total number of shore flies collected during the season from all wetlands consisted of *Allotrichoma simplex* (Loew) (7.7%), *Discocerina obscurella* (Fallén) (48.8%), *Hydrellia griseola* (Fallén) (9.2%), *Hydrellia tibialis* Cresson (4.5%), *Paralimna punctipennis* (Wiedmann) (3.5%), *Polytrichophora orbitalis* (Loew) (4.6%), *Scatella stagnalis* (Fallén) (4.82%) and *Typopsilopa atra* Loew (3.1%). The abundance of these species ranged from occasional (occ) to very abundant (va) (Table 1). All other species were rare (r) and were represented by fewer than 100 individuals (Tables 1–4). May samples from the Heron and Mallard wetlands (Tables 2 and 3) and October collections from Miami Trace (Ta-

ble 4) did not contain shore-fly specimens (Fig. 1). Although initial collection of shore flies from Mallard and Heron wetlands started in June and July, respectively, species accumulation patterns are similar (Fig. 1). Shore-fly species accumulation in the Miami Trace wetland started in May and approached asymptote during September (Fig. 1).

In the Mallard and Heron wetlands, the abundance of *Allotrichoma simplex, Polytrichophora orbitalis,* and *Discocerina obscurella,* increased during August and September (Table 2 and 3), respectively, while *A. simplex* and *Hydrellia griseola* appeared in May collections and abundance continued to increase through July in the restored wetlands at Miami Trace (Table 4). Although a single *Po. orbitalis* adult was collected in May in the restored wetland, additional specimens were not captured until July (Table 4). *A. simplex* and *Po. orbitalis* consume decaying organic matter (Foote and Eastin 1971, Foote 1995).

The abundance of two leaf-mining species, *Hydrellia griseola* and *Hydrellia tibialis,* and *T. atra* increased dramatically during July through August, and September in Miami Trace and Winton Woods wetlands, respectively (Tables 2–4). Also, appreciable numbers of *Paralimna punctipennis* and *Scatella stagnalis* were found in Mallard and Heron wetlands (Tables 2 and 3) during September. *Sc. stagnalis,* and *Pa. punctipennis* feed on cyanobacteria and diatoms, respectively (Foote 1995). *Hyadina albovenosa* Coquillett, *Hyadina binotata* (Cresson), *Hyadina pruinosa* (Cresson), and *Hydrellia formosa* Loew were rare (r) species (Table 1) and collected early in the season from grass shore habitat at Heron Wetland (Table 3). Although relatively large numbers of *Parydra* (Table 5) and *Notiphila* species were routinely collected in aquatic habitats and mature wetlands in Ohio (Steinly 1978, Todd and Foote 1987, Larson and Foote 1997), respectively, *Notiphila adusta* Mathis, *Notiphila loewi* Cresson, *Notiphila pauroura* Mathis, *Notiphila*

Table 2. Shore-fly community of Mallard Wetland at Winton Woods County Park.

	June	July	Aug.	Sept.	Oct.		Total
Allotrichoma simplex	—	—	17	43	21	=	81
Dichaeta caudata	—	—	—	—	2	=	2
Discocerina brunneonitens	—	—	5	29	9	=	43
Discocerina obscurella	3	20	175	1116	839	=	2153
Ditrichophora exigua	—	—	—	1	—	=	1
Hyadina binotata	—	—	—	1	—	=	1
Hyadina pruinosa	—	1	—	—	—	=	1
Hydrellia griseola	1	8	27	149	94	=	279
Hydrellia ischiaca	—	—	1	—	—	=	1
Hydrellia tibialis	—	—	—	99	17	=	116
Hydrochasma leucoproctum	—	—	—	—	24	=	24
Leptopsilopa atrimana	—	—	1	—	—	=	1
Lytogaster excavata	1	—	—	—	—	=	1
Nostima scutellaris	—	—	—	1	2	=	3
Notiphila adusta	—	—	2	—	—	=	2
Notiphila loewi	—	1	—	1	—	=	2
Notiphila pauroura	2	6	—	23	3	=	34
Notiphila phaeopsis	—	—	8	33	—	=	41
Ochthera anatolikos	—	—	—	1	1	=	2
Paralimna punctipennis	—	—	6	51	22	=	79
Parydra aquila	—	3	4	3	—	=	10
Parydra breviceps	1	7	6	43	—	=	57
Parydra quadrituberculata	4	—	39	—	—	=	43
Polytrichophpora orbitalis	—	—	—	152	16	=	168
Psilopa dupla	—	4	2	2	—	=	8
Ptilomyia enigma	—	—	—	11	16	=	27
Scatella obsoleta	—	—	—	—	7	=	7
Scatella paludum	—	—	—	—	5	=	5
Scatella stagnalis	—	—	4	63	10	=	77
Typsilopa atra	—	4	1	11	—	=	16
Zeros flavipes	—	—	3	15	4	=	22
Total =	12	54	301	1848	1092	=	3307

phaeopsis Mathis, *Parydra aquila* (Fallén), *Parydra breviceps* Loew, and *Parydra quadrituberculata* Loew were rare (r) in all newly established wetlands. Additionally, *Scatella favillacea* Loew, *Scatella obsoleta* Loew, *Scatella paludum* (Meigen), and *Sc. stagnalis* were found on filamentous algal mats in the spring at Miami Trace, but the habitat was submerged by a mid-summer torrential rainfall and *Scatella* species and *Setacera atrovirens* (Loew) were not found after 18 August. In contrast, *Sc. obsoleta* and *Sc. paludum* were collected from Mallard Wetland at Winton Woods in late summer (Table 2).

A comparison of Mallard and Heron shore-fly communities with the Sorenson index suggests that the constructed wetlands contained similar assemblages (Table 6) while comparison of Miami Trace with both Winton Woods localities yielded lower similarity values (Table 6). Community diversity values (H') of 1.10 (Heron), 0.83 (Miami Trace), and 0.67 (Mallard) compared with a *t*-test suggest that shore-fly communities within each wetland were significantly different.

DISCUSSION

Monthly increases in *A. simplex*, *D. obscurella*, and *Po. orbitalis* abundance (Tables 2–4) suggest that detritivore colonization, continuous immigration, and/or the growth of newly established communities

Table 3.   Shore-fly community of Heron Wetland at Winton Woods County Park.

	July	Aug.	Sept.	Oct.		Total
Allotrichoma simplex	1	—	41	2	=	44
Diachaeta caudata	—	—	—	3	=	3
Discocerina brunneonitens	—	—	1	—	=	1
Discocerina obscurella	—	2	39	155	=	196
Hyadina albovenosa	34	—	1	—	=	35
Hyadina binotata	10	—	2	—	=	12
Hyadina pruinosa	1	—	—	—	=	1
Hydrellia formosa	6	1	—	—	=	7
Hydrellia griseola	—	4	82	16	=	102
Hydrellia tibialis	—	—	47	—	=	47
Lytogaster excavata	3	—	4	1	=	8
Nostima scutellaris	2	1	5	—	=	8
Notiphila adusta	—	1	8	—	=	9
Notiphila loewi	—	—	5	1	=	6
Notiphila pauroura	—	—	22	—	=	22
Notiphila phaeopsis	—	2	18	—	=	20
Paralimna punctipennis	—	3	70	6	=	79
Parydra aquila	—	—	5	—	=	5
Parydra breviceps	—	3	10	—	=	13
Parydra quadrituberculata	—	—	3	—	=	3
Philygria debilis	1	—	—	—	=	1
Polytrichophora orbitalis	—	—	30	6	=	36
Ptilomyia enigma	—	—	3	—	=	3
Scatella stagnalis	—	—	145	2	=	147
Typsilopa atra	13	9	58	45	=	125
Zeros flavipes	—	—	14	2	=	16
Total =	71	26	613	239	=	949

were not adversely affected by low quantities of decaying organic matter. Although shore-fly primary consumers were collected from Miami Trace and Mallard wetlands, approximately 60 to 78% of the specimens collected were detritivores, respectively (Table 1). This investigation confirms that shore-fly primary consumers and detritivores rapidly colonize restored and constructed wetlands in Ohio. Although Scheiring and Deonier (1979) proposed that resource quantity increased the richness and abundance of well-adapted ephydrid species in transient habitats, the low detritus quantities, and abundance of detritivores in newly restored wetlands supports Batzer and Wissinger's (1996) contention that detritivore colonization was not affected by the growth of macrophytes and algae, and insect abundance remained constant or increased when macrophytes were cut and debris removed.

The early colonization of restored wetland ecosystems by large numbers of *A. simplex, D. obscurella,* and *Po. orbitalis* suggests these species are important components in the early development of viable food chains that sustain diverse predaceous invertebrate and/or vertebrate communities. During late summer, increases in the populations of *Hydrellia griseola, Hydrellia tibialis* (i.e., leaf miners), *T. atra,* and a diatom feeder, *Paralimna punctipennis* are associated with increased density and growth of macrophyte and diatom food resources. *Typopsilopa* spp. have been associated with the consumption of decaying tissue on damaged monocot stems (Keiper et al. 2001). The increase of micro- and macrophyte production represents a significant augmenta-

Table 4. Shore-fly community of a new wetland at Miami Trace County Park.

	May	June	July	Aug.	Sept.		Total
Allotrichoma simplex	23	72	102	80	—	=	277
Discocerina obscurella	—	—	5	24	3	=	32
Ditrichophora exigua	—	—	—	2	—	=	2
Hyadina binotata	—	—	3	—	—	=	3
Hydrellia griseola	4	20	34	4	—	=	62
Hydrellia tibialis	—	9	11	33	—	=	53
Hydrochasma leucoproctum	—	—	—	—	3	=	3
Notiphila adusta	—	1	—	1	1	=	3
Ochthera anatolikos	—	2	2	—	—	=	4
Paralimna punctipennis	—	1	2	3	5	=	11
Parydra quadrituberculata	4	—	—	—	—	=	4
Pelina truncatula	—	—	1	—	—	=	1
Philygria debilis	33	—	2	—	—	=	35
Polytrichophora orbitalis	1	—	3	4	7	=	15
Psilopa dupla	—	—	3	—	—	=	3
Scatella favillacea	25	—	—	—	—	=	25
Scatella obsoleta	11	—	1	—	—	=	12
Scatella paludum	1	—	1	—	—	=	2
Scatella stagnalis	—	2	5	1	—	=	8
Setacera atrovirens	1	—		—	—	=	1
Typsilopa atra	—	1	5	—	—	=	6
Total =	103	108	180	152	19	=	562

tion of nutrient resources in newly restored wetlands and a probable increase in food wed complexity. Early colonization, species accumulation (Fig. 1), and temporal abundance increases of shore-fly species (Tables 2–4) may be characteristic of initial stages of food chain development and the establishment of complex food web interactions.

Although *Parydra aquila, Parydra breviceps,* and *Parydra quadrituberculata* were collected in semi-aquatic grass, sand and mud shore habitats in Ohio (Table 5) (Steinly 1978), the rarity of these species in newly restored wetlands (Tables 1–4) suggests that obligate diatom species were not abundant. Species of *Parydra* are specialist on particular diatoms species (Bischof and

Deonier 1985). Only a few individuals within the genus *Parydra* were collected at Miami Trace and suggests that *Parydra* species are late colonizers and/or diatom spp. were not abundant.

Hydrellia formosa and four *Notiphila* species colonized the Winton Woods sites, while one species of *Notiphila* was collected at the Miami Trace wetland (Table 1). In all probability, the richness and abundance of *N. adusta, N. loewi, N. pauroura,* and *N. phaeopsis* is dependent on detritus accumulation on the root surfaces of different species of emergent vegetation (Larson and Foote 1997) at Heron Wetland. Although eight *Notiphila* species were collected during 1995 through 1998 from the older Mi-

Table 5. Relative abundance of shore flies in Ohio aquatic habitats.

	Grass Shore	Mud Shore	Sand Shore
Parydra aquila	occ	r	r
Parydra breviceps	occ	c	occ
Parydra quadrituberculata	occ	occ	occ

Abbreviations: c = common; occ = occasional; r = rare.

Table 6.   Sorenson Index of Similarity values for a newly created and two constructed wetlands in Ohio.

	Mallard Wetland Winton Woods	New Wetland Miami Trace
Heron Wetland Winton Woods	0.81*	0.51*
Mallard Wetland Winton Woods	—	0.65*

* Comparison of community diversity values P < 0.001.

ami Trace complex of restored wetlands (Steinly, unpub. data), only a few adults were collected from the restored wetland (Table 1) and the low richness and abundance of *Notiphila* spp. are attributed to the paucity of emergent vegetation in the restored wetland.

The abundance of detritivores and leafminers, diatom consumers, i.e., *Pa. puncti-pennis*, and *Sc. stagnalis*, a possible secondary consumer of damaged monocots stems, *T. atra*, and a cyanobacteria feeder suggests that at least five main nutrient sources were exploited by shore flies during the early stages of wetland restoration. During the initial stages of wetland restoration, the abundance of detritivores, leafminers, a secondary consumer, an algivorous species, and consumers of cyanobacteria (e.g., *Nos-tima* and *Hyadina* species) suggest that the rudiments of viable food chains were present in late spring and early summer within the Mallard and Heron wetlands. Early collection, the increase of shore-fly richness and abundance (Tables 2–4) during the summer months, and the utilization of five different nutrient resources, i.e., algae, macrophytes, damaged monocot stems, detritus, and cyanobacteria suggest that shore-fly colonization provides a foundation for the development of diverse food chains and food webs. The successful restoration and maturation of wetland food chains is dependent on establishment and growth of aquatic micro- and macrophyte and microbe communities, accumulation of detritus, and concurrent colonization and establishment of resident primary consumers and detritivores, i.e., shore flies that move nutrients into food webs. Once detritus, bacterial, and plant nutrients are assimilated by shore

flies, wetland production is accessible to predaceous invertebrates (e.g., *Ochthera anatolikos* Clausen) and vertebrates. The abundance of insect consumer populations has been linked to waterfowl reproductive success that is dependent on the quantity and quality of insect protein (Driver et al. 1974). In some instances early emergence of the Chironomidae (Diptera) provides a large quantity of protein (McLaughlin and Harris 1990), while waterfowl utilize shore flies and other families of Diptera for food later in the season.

Superficially, the significant difference in H′ values and the high Sorenson similarity value for the Mallard and Heron richness comparison are contra indicators. Although a Sorenson index of 0.81 and monthly species accumulation (Fig. 1) suggest that shore-fly community richness values in Mallard and Heron wetlands are comparable, the significant difference in H′ values ($P < .0001$, t = −22.77, df = 2540) suggests that these wetlands harbored unique species assemblages. The difference in shore-fly assemblages is attributed to extreme variation of individual species abundance within each wetland (Table 1). Although, the relatively high index of similarity (Table 6) suggests that biological and physical conditions were comparable in Mallard and Heron wetlands, the variation in shore-fly species abundance and the difference in the abundance of detritivores and primary consumers suggest that ecosystem development and/or maturation within each wetland was asynchronous.

Comparison of Miami Trace to Mallard and Heron Wetlands yielded low Sorenson indices (Table 6), differences in species accumulation patterns, and H′ values that
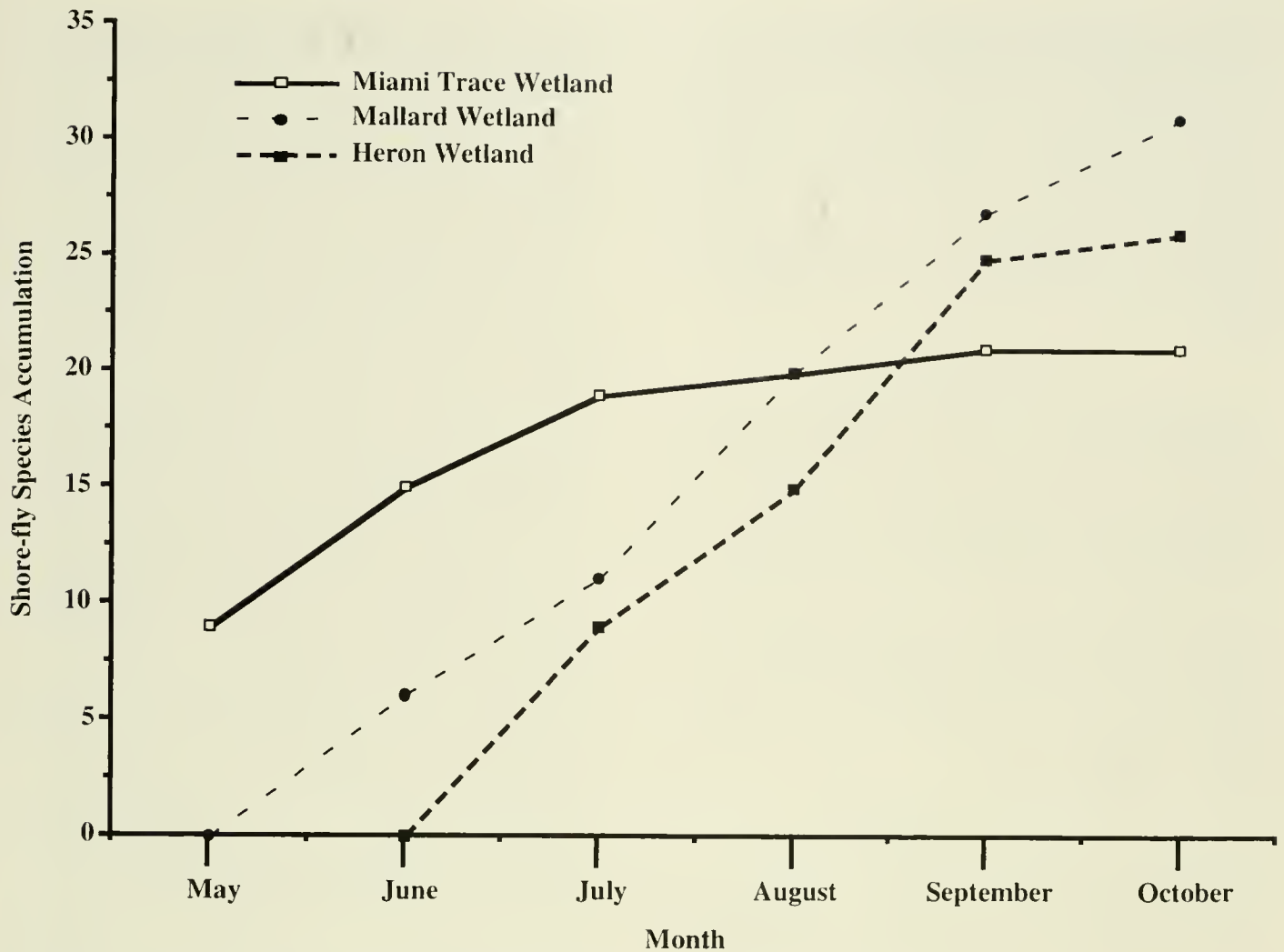
Fig. 1. Shore-fly species accumulation in newly constructed and restored wetlands.

were significantly different ($P < 0.001$, t = 9.38, df = 922 and t = -5.68, df = 863, respectively). These differences suggest that the Miami Trace species assemblage was unique. The difference in shore-fly communities is attributed to local precipitation frequency and quantity, and disparate physical and biological conditions that are unique to restored and/or constructed wetlands. Further, the difference in shore-fly communities at Miami Trace as compared to the Winton Woods wetlands is confirmed by early colonization of shore flies in May vs. June and July and early development of species accumulation asymptote (Fig. 1) in the restored wetlands.

The importance of insect primary consumers and detritivores within food chains has been acknowledged (Batzer and Wissinger 1996, Hansen and Castelle 2000), but a comprehensive understanding of insect herbivore, detritivore, and predator communities in restored wetlands is wanting. The scarcity of information is attributed to the daunting task of identifying large numbers of invertebrate species, and species interactions within and between food webs, and the lack of sampling in shoreline habitats (Keiper et al. 2002). Additionally, the number of food chain interactions and food web dynamics may vary from one geographic region to another.

The Ephydridae are a trophically diverse family that provides a unique opportunity to study the movement of wetland production into food webs because shore-fly species are routinely collected and abundant in wetlands. Without the colonization of wetlands by shore flies and/or other insect families that contain primary consumers and detritivores, the movement of primary production and detritus into food chains and development of food webs may be limited. Design and management of wetlands that

promotes the colonization and growth of in-
sect communities to expedite the cycling of
plant resources (i.e., primary production)
and energy transfer will provide a founda-
tion for diverse food chains and complex
food webs that sustain an abundance and
variety of invertebrate and vertebrate spe-
cies.

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